Conference Paper

Characteristics and Sensing Properties of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ System for CO Gas Sensors

J.C. Ding, Z.P. Wu, H.Y. Li, Z.X. Cai, X.X. Wang, and X. Guo

Laboratory of Solid State Ionics, School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, P. R. China

Abstract

A series of nanostructured $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ perovskite-type (x ranging from 0 to 1) were prepared using the co-precipitation method. CO gas sensing properties of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensors were performed. $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor showed the highest response at 250 °C (S=52.8).

Keywords: $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$, nanoparticles, CO sensor, $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$

Corresponding Author: X. Guo; email: xguo@hust.edu.cn

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1. Introduction

Carbon monoxide (CO) is colorless, odorless and yet highly toxic gas; it can attack hemoglobin from the blood, preventing the supply of needed oxygen to different parts of human body [1]. Sensors for detecting CO gas have been widely used in many areas, for example, the control of industrial wastes and vehicle emissions, the monitoring of indoor atmosphere and coal mine explosion [2].

Several substituted rare-earth-transition-metal oxides of the perovskite structure (ABO_3) have been used as CO sensors. Among these oxides, $LaCoO_3$ and $LaFeO_3$ exhibit excellent CO sensing performance. In our previous work, the characteristics and sensing properties of the $LaCo_{1-x}Fe_xO_3$ system for CO gas sensors have been studied and the $LaCo_{0.3}Fe_{0.7}O_3$ one demonstrated maximal response.

In addition, $NdMO_3$ (M = Co, Fe, etc.) exhibits good ability in CO sensing or CO catalytic oxidation. Among them, $NdCoO_3$ is an excellent sensing material with high sensitivity towards the CO [3-4]. It has been studied for CO sensing and exhibits excellent performances; for example, $NdCoO_3$ thin film showed a good response (about 15%) for CO concentration until 0.1% and the optimal working temperature was found to be around 300 °C [5]. On the other hand, $NdFeO_3$ was reported to have good gas-sensing properties for CO. For examples, the $NdFeO_3$ sensor showed a response of 1215% to 0.03% CO gas at 170°C [6]. In addition, some mixed solution compounds, such as $NdFe_{1-x}Co_xO_3$ [6] and $La_{1-x}Nd_xFeO_3$ [7], have been prepared and their structural, electrical, and gas sensing properties have been investigated.

Based on the above analyses, $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ could be very promising for the CO sensing; there must be an optimal *x* value for obtaining the best CO sensing performance. In this work, we prepared $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles by co-precipitation and investigated the CO sensing properties of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ system, with an aim to exploit the optimal chemical composition for the best CO sensing performances. It is discovered that the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor shows the best CO sensing performances.

2. Methods

A chemical co-precipitation method was used to prepare $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles (x = 0÷1.0 with increment 0.1). The stoichiometric amounts of corresponding metal nitrates were dissolved in deionized water. H_2O_2 was then added to oxidize Co(II) to Co(III). Afterwards, NaOH solution was added to adjust the pH value to 11~12. The resulted precipitate was rinsed with deionized water until pH=7, and dried at 80°C for 2 h. Finally, $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles were obtained by calcination at 650°C for 6 h in air.

The gas sensors were fabricated by dipping. The $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles were dispersed in ethanol ultrasonically. Then, the suspension was dripped on the FTO substrate, on which a gap of about 60 °m was cut by laser. Afterwards, the samples were dried naturally to remove ethanol. Platinum wire was connected to the FTO using Ag paste.

The crystal structure of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ powder was checked by X-ray diffraction (XRD) (SHIMADZU XRD-7000S) in the 2θ range of 10-90°. The microstructure of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensors was analyzed using scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectroscope (EDS). The sensor resistance was collected automatically every second using a Keithley 2450 Source Measurement Unit (SMU). A flow system comprising two mass flow controllers was used to introduce gases with specified concentrations of CO in N_2 into the sample chamber at a flow rate of 500 standard centi-cubic per minute (SCCM).

3. Results

3.1. Phase determination and microstructure

Fig. 1 shows the XRD patterns of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles prepared by co-precipitation; all of them are single phase. The corresponding spectra of rhombohedral $LaCoO_3$ (orange line), orthorhombic $LaFeO_3$ (violet line), $NdCoO_3$ (red line), and $NdFeO_3$ (blue line) are reported for comparison. When x = 0, the $LaCo_{0.3}Fe_{0.7}O_3$ nanoparticles have the transient phases between $LaCoO_3$ and $LaFeO_3$. When x = 1, the $NdCo_{0.3}Fe_{0.7}O_3$ nanoparticles have the transient phases between $NdCoO_3$ and $NdFeO_3$. In addition, the angle of the Bragg reflections of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles increases with an increase of Nd content x. This is because the radius of the Nd^{3+} (98 pm) ion is smaller than that of La^{3+} (103 pm), when the La^{3+} is replaced by Nd^{3+} at A site,

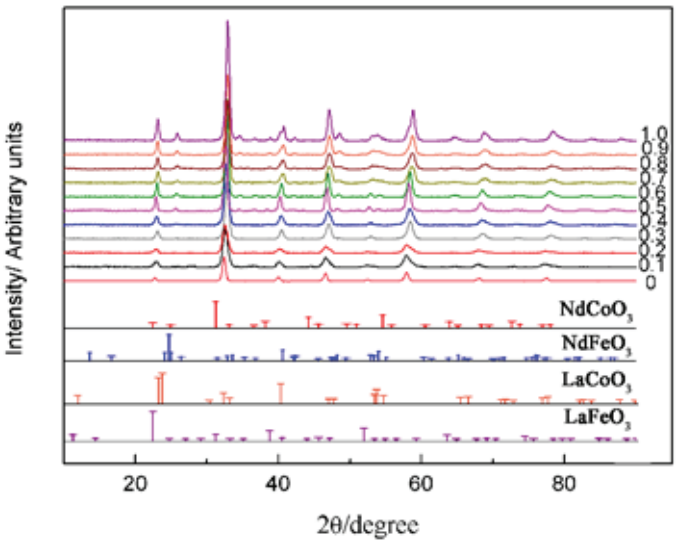

Figure 1: XRD patterns of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ nanoparticles ($o \leq x \leq 1$).

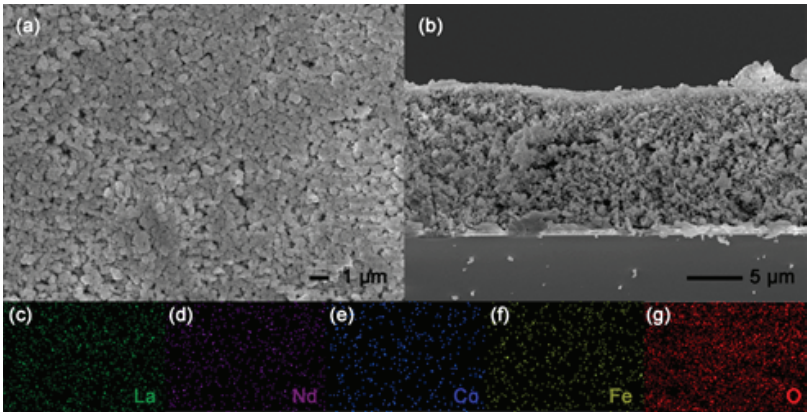

Figure 2: SEM micrographs of $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor: (a) surface, (b) cross-section. EDS elemental mapping showing distribution of (c) La, (d) Nd, (e) Co, (f) Fe and (g) O elements in $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor.

the lattice parameters should become smaller with increase of the Nd concentration. According to the Bragg formalum, the diffraction angle becomes larger.

Typical SEM micrographs of the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor are shown in Fig. 2. From the Fig. 2a, we can see that the sensing layer is highly porous and the original morphology of particles is well maintained, which is preferred for gas-sensing applications. A clear boundary exists between the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ layer and the FTO substrate, as indicated in Fig. 2g. Good adhesion between the sensing layer and the substrate is also obvious. The representative EDS elemental mappings of the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor are illustrated in Figs. 2c-g suggesting that the elements La, Nd, Co, and Fe show the homogeneous distribution throughout the sensor.

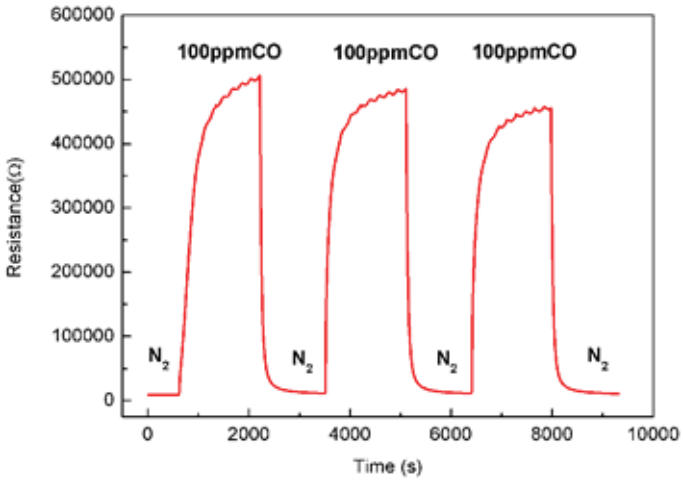

Figure 3: Resistance of $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor under alternating cycles of 100 ppm CO and N_2 at 250°C.

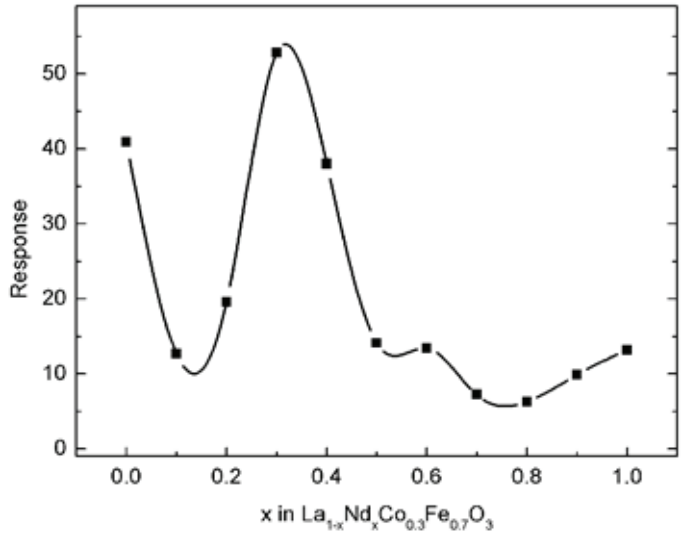

Figure 4: Response of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensor as a function of x ($0 \leq x \leq 1$) for 100 ppm CO at 250°C.

3.2. Sensing Properties to CO

The resistance of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensors (x = 0÷1.0 with increment 0.1) were tested under alternating cycles of 100 ppm CO and N_2 at 250°C; the resistance curve of the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor under alternating cycles of 100 ppm CO and N_2 at 250°C is shown in Fig. 3. When 100 ppm CO was introduced, the sensor resistance increased, and a resistance decrease was observed when CO was cut off. A good repeatability was achieved among individual cycles. The sensor response is defined as: $S = R_{CO}/R_{N_2}$, here R_{CO} is the sensor resistance in the presence of CO, and R_{N_2} is the resistance in N_2. It can be calculated from the resistance curve.

Fig. 4 shows the response of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensors as a function of *x* at 250°C. As one can see, the responses of the $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ sensors fluctuate with the change of *x*. Among them, when *x* = 0.3, the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor displays an excellent response (*S* = 52.8).

4. Conclusion

The CO sensing properties of $La_{1-x}Nd_xCo_{0.3}Fe_{0.7}O_3$ were systematically investigated as a function of Nd concentration. Among them, the $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ sensor showed excellent CO sensing performance. Therefore, $La_{0.7}Nd_{0.3}Co_{0.3}Fe_{0.7}O_3$ is a very promising material for the CO sensors.

5. Acknowledgement

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